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AUTHOR Owen, John
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ABSTRACT

This document focuses on implications for the design of preservice education programs for science and mathematics teachers. It is assumed that the goal is to prepare effective teachers, so the literature devoted to teacher effectiveness is first examined. This material is primarily aimed at improvement in Australia, but the concepts and issues discussed are seen as broader-based. The major sections of this text are: (1) A Summary of Initiatives in the Study of Teacher Effectiveness; (2) Teacher Effectiveness in the Sciences; (3) Trends in the Preservice Education of Science Teachers; (4) Teacher Effectiveness in Mathematics; (5) Trends in the Preservice Education of Mathematics Teachers; and (6) Implications for Local Teacher Education Programs in Science and Mathematics. This material concludes with references and an appendix. (MP)

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PAPERS ON THE EDUCATION OF

SCIENCE AND MATHEMATICS TEACHERS

NO. 1

THE RECENT LITERATURE: IMPLICATIONS FOR THE DESIGN OF PRESERVICE PROGRAMS

BY

JOHN OWEN

Tertiary Education Research Unit, Melbourne State College
Carlton, Victoria. February 1980.

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A SUMMARY OF INITIATIVES IN THE STUDY OF TEACHER EFFECTIVENESS

Before the topic of appropriate pre-service courses for teachers is tackled it seems appropriate to consider just what we are aiming at; in this case it is assumed that we wish to prepare effective teachers of mathematics and/or the sciences. To consider these questions, it is necessary to examine the literature devoted to teacher effectiveness, a topic which has been a major focus of attention during the past twenty years.

Generally, teacher effectiveness is considered in terms of the behaviours of teachers which promote student change, particularly in cognitive learning. It is important to be aware that factors, other than those associated with teacher characteristics, affect student learning. Student home background (socio-economic status, hereafter SES), school context, and individual student characteristics are also important sets of variables which relate to student performance (see for example, Comber and Keeves, 1973).

The majority of teacher effectiveness studies are focussed on what happens in classrooms, that is on the instructional phase of teaching. It must be borne in mind that school based curriculum development can be seen as having five phases; a situational review of the school and neighbourhood, the formulation of goals for courses, the building of programs, instruction in classrooms, and monitoring of courses for review purposes (evaluation). Very little research has been mounted on what contributes to effective curriculum development by teachers (see Skilbeck, 1975). However, all teacher education courses in Australia should acknowledge the need to prepare teachers to cope with tasks of a wider and more complex nature than those which focus narrowly on classroom instruction. In the absence of information about these broader aspects, the review of teacher effectiveness, presented below, must dwell on classroom analysis.

Teacher Effectiveness - Some General Findings

Barr and Dreeben (1977) have undertaken a comprehensive review of teacher effectiveness research. Their summary examines findings in

order to discover:

(1) What actually goes on in classrooms, and
(2) What methods of teaching or characteristics of teachers promote learning.

Early studies of classroom processes in the tradition established by Flanders suggest that:

(1) Teachers do most of the talking in lessons.
(2) It is likely that the majority of teacher talk is in the form of lecturing.
(3) The majority of interactions between teachers and students are initiated by teachers.
(4) Student talk is mainly in the form of responses to teachers.

Most studies in this tradition have been correlational, rather than experimental in design. A synthesis of the results of many studies of this nature enable some conclusions to be made regarding effective teacher characteristics (see for example, Rosenshine and Furst, 1973). Nine teacher variables have consistently yielded significant correlations with student achievement. These are:

(1) Clarity; clear explanation of points and concepts.
(2) Variability; flexibility of procedure, use of a variety of materials and displays.
(3) Enthusiasm; interest in subject matter and involvement with students.
(4) Task orientation; emphasis of thought stimulation and emphasis on information acquisition by students.
(5) Criticism; a negative effect, the harsher teacher criticism the less achievement by the student.
(6) Indirectness; emphasis on the use of student ideas and responses in teaching procedures.
(7) Opportunity to learn; time spent on the subject.
(8) Use of structuring comments; ability to use statements which provide students with knowledge of what is about to take place, or to summarize what has taken place, and

/3.

(9) Questioning techniques; the ability to elicit "higher order" as well as factual responses from students through questioning.

Research of this 'molecular' nature has drawn its share of critics, the major criticisms concern the design of the research or the relationship between the relatively short durations of data collection vis a vis the 'real' long term situations under which learning takes place in the classroom. During the 1970s a tradition has emerged which employs a 'molar' approach; examining what teachers do over longer periods of time, and using alternative criterion (dependent) and independent variables. Two allied developments of note are those concerned with classroom management and the use of time in lessons. In his study of classroom management by primary teachers, Kounin (1970) described the following teacher behaviours as being associated with involvement of students in learning:

(1) 'Withitness'; an ability to monitor events in the classroom regardless of the teachers current activity.
(2) Smoothness; the maintenance of a smooth flow of activities, particularly at points of transition from one activity or topic to another.
(3) Momentum; the absence of 'slow downs'
(4) Group alerting; the continuous attention by the teacher to non attending students, and
(5) Overlappingness; the ability to deal with two or more things at the same time.

At the foundation of this management approach is the notion that teachers need to make many classroom decisions in short time intervals. Teaching requires an ability to use large numbers of diagnostic, instructional and therapeutic skills, tailoring their use to specific contents and situations given the specific needs of the moment.

Studies of the use of time have culminated in the Beginning Teacher Evaluation Study (BTES) (Fisher, et al, 1978; Berliner 1979), conducted in California. In studying differential student outcomes as they relate to time, distinctions have been made between:

(1) Allocated time: the maximum amount of time allotted to the subject area,

(2) Engaged time: that part of the allocated time during which the students pay attention to the task, and

(3) Academic learning time (ALT): the time spent on tasks that a student can perform with a high chance of being successful.

The BTES study suggests that student achievement is dependent on ALT. The implication of these findings is that teachers need to know the capabilities of their pupils, how these change with time, and also how to arrange or match the learning conditions in order to maximise the use of the time available for each student. In summarizing the results, it was reported that:

> One can construct the image of the ideal class: there is a clear focus on cognitive learning, the students expect to work and are held responsible for doing so; the teacher cares about the students and wants to help them learn, teachers and students interact comfortably and frequently on work activities (Fisher, et al, 1978:37).

The preceding discussion has concentrated on general findings about teacher effectiveness, most of which are concerned with expository teaching, and related to cognitive outcomes. Now it is possible that there may be variations in expected outcomes between subjects in the curriculum and that different subjects may lend themselves to different modal techniques of instruction. There may, therefore, be student-teacher interactions which are derived from the logic of the subject in relation to its place in the curriculum. This review now turns towards the two subjects under review, science and mathematics, with a view to determining specific findings relating to good teaching in these areas.

Introduction

An important question here is to ask, at the outset, whether effective science teaching requires a set of knowledge and skills to be acquired by the teacher which are unique to this area of the curriculum. If this is so, then the education of science teachers may well be different, or diverge from, the education of teachers of other subject areas. One way that the knowledge and skills expected of science teachers may be assembled is to consider the objectives of science teaching and the role the sciences play in the education of school students.

Science has occupied a place in the curriculum of most schools in western democracies throughout this century. Its position has been defended from a range of viewpoints. On purely intellectual grounds, philosophers have argued for science in the curriculum because it provides a unique form of knowing. We have also witnessed a more prosaic thrust; exemplified by the initial funding and promotion of single subject science courses during the 1960s. In America, there was great concern that the USA was lagging behind the USSR in science and technological development. More recently, during the period when the proportion of students in the 11-16 age group at school has increased, a major argument mounted for science is that the knowledge and skills taught in the subject are necessary for all educated individuals.

The National Science Teachers Association (NSTA) in the USA have supported this notion for some time. In a 1964 publication of the Association, it was stated that:

> Education in the sciences must be based up on the kind of information that has survival value and strategies of enquiry that facilitate the adoption of knowledge to new demands.

The idea of 'scientifically literate' citizens has dominated discussions about a rationale for school science education in the 1970s. Martin (1972), in a review of trends in science education, sees an extension

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of the concept to accommodate the 'propensities of science', the tendencies for those affected to behave in certain ways. He argues that:

> Science educators should aim, not only at having students acquire knowledge, skills and understandings, but also at having students acquire the propensities to use such knowledge, skills and understandings in their lives. (Martin, 1972:160)

Consistent with this view of a broadening influence of science education, Martin considers that science teaching in schools must be in harmony with social and moral questions related to other parts of the traditional curriculum:

> Whatever the details of the integration of moral and scientific education, one things is clear; the ways of science and the ways of morality are intimately connected. The intellectual virtues characteristic of science - honesty, objectivity, impartiality and rationality - are moral virtues. Science education, broadly conceived, ought to foster these virtues in both scientific and moral contents. Let us venture to hope that in the future the ways of science will become meaningful to students and become their ways. (Martin 1972:160)

Scientific literacy was seen to be achieved through the development of concepts, process skills and attitudes. In a 1971 NSTA position paper, a scientifically literate person was defined as one who:

- Uses science concepts, process skills, and values in making everyday decisions as he interacts with other people and with his environment,
- Understands that the generation of scientific knowledge depends upon the inquiry process and upon conceptual theories,
- Distinguishes between scientific evidence and personal opinion,
- Identifies the relationship between facts and theory,
- Recognizes the limitations as well as the usefulness of science and technology in advancing human welfare,

- Understands the interrelationships between science, technology and other facets of society, including social and economic development,
- Recognizes the human origin of science and understands that scientific knowledge is tentative, subject to change as evidence accumulates,
- Has sufficient knowledge and experience so that he can appreciate the scientific work being carried out by others,
- Has a richer and more exciting view of the world as a result of his science education,
- Has adopted values similar to those that underlie science so that he can use and enjoy science for its intellectual stimulation, its elegance of explanation, and its excitement of inquiry, and
- Continues to inquire and increase his scientific knowledge throughout his life.

The general principles and objectives for teaching the sciences just outlined seem to be still appropriate as we approach the 1980s. A broad general education in science should provide every student with basic knowledge about the physical and biological environment, an understanding of methods of scientific investigations, an appreciation of the limits of enquiry, and some knowledge of how research and technology affect daily life. Specialised education in science is also required for students who have particular abilities and interests in scientific fields, both traditional and new.

A corollary of the principle of education in the sciences for all is that materials and methods should be developed to cater for the wide range of individual differences amongst students. The work of cognitive psychologists has provided evidence that a group of individuals at any particular age show variation in their level of cognitive development and this has implications for the ways in which science education problems can be approached. Research has identified other dimensions along which individuals may vary. These differences affect students' interests and approaches to specific problems in science. One important development, which has been adopted by some developers of materials for science, has been mastery learning. Bloom (1976) contends that the vast majority of students can absorb knowledge if schools approach

instruction in a sensitive fashion. Proponents of his methods reject the normative approach to achievement (over a fixed time) and advocate a mastery approach for all students (fixed outcome) with time as the variable. They argue for curriculum approaches which include provision for differential rates of learning and variation in student entry level characteristics.

The 'Ideal Science Teacher'

It is not surprising, given the enormous volume of research and development during the past two decades, that some attention has focussed on the identification of the characteristics of the 'ideal science teacher'. Science teachers' associations have been at the forefront of this endeavour. Several of the salient contributions to this area of investigation are now examined.

Opening the Annual Conference of the South Australia Science Teacher Association in 1975, Greg Ramsey presented several important perspectives of schooling as they applied particularly to science education in this country. When discussing professionalism, he suggested that an effective science teacher:

(1) Is well educated in science and the liberal arts,
(2) Possesses a functional philosophy of education and technical skills of teaching,
(3) Continues to grow in knowledge and skill through his career,
(4) Insists on a sound educational environment in which to work,
(5) Maintains his professional status,
(6) Contributes to the improvement of science teaching, and
(7) Takes a vital interest in the quality of future science teachers. (Ramsey, 1976:3)

These are broad aims well suited to a charter of a professional subject teachers' association. Their implications for formal preservice education might be a suitable topic for discussion. It is apparent that Ramsey places strong emphasis on the affective or attitudinal aspects of teacher behaviour.

Other studies have taken a slightly narrower focus, concentrating on the characteristics of science teachers which relate to the development of curriculum, including instruction in the classroom. For example, the American National Association of Biology Teachers conducted a study in which they asked secondary school teachers, school administrators, biologists in educational institutions and in industry, and professors of education to rate factors thought to be desirable in biology teachers. Twenty-one were rated 'usually important' or 'always important' by the entire group. They could be classified into three categories:

(1) Intrinsic Personal Traits:
   a) Interest and enthusiasm for biology,
   b) Adequacy of self concept,
   c) Evidence of ingenuity,
   d) Emotional poise and self-concept,
   e) Evidence of creativity,
   f) Apparent interest in self improvement.

(2) Student-Teacher relations
   a) Ability to encourage self-motivation in students,
   b) Ability to inspire self-confidence,
   c) Concern for personal involvement by students in learning activities,
   d) Ability to facilitate student interaction,
   e) Understanding of individual needs,
   f) Efforts to provide for different student interests and needs,
   g) Efforts to encourage students to develop higher level skills such as advancing hypotheses and theories.

(3) Skills and proficiencies of a science teacher
   a) Concern for student understanding of essential science processes and concepts,
   b) Skill in use of a variety of materials and methods,
   c) Thought provoking laboratory experiments,
   d) Classroom climate which facilitates learning.

(Dieter and Hounshell, 1975:139-146)

In another American study, Simpson and Brown (1977) surveyed groups

representing: high school science teachers, science supervisors (inspectors), school principals and college and university science educators. Using a technique of progressive focussing on outcomes (the Delphi technique), the researchers sought to gain a consensus as to what should be the basic competencies of science teachers entering the profession. Using a statistical technique known as factor analysis, seven fundamental areas of skills were uncovered. These were:

Fundamental Skill Area	Example of a Competency Statement
Products and Processes	Be able to define science and discuss intelligently the process and values associated with scientific endeavours.
Professional Knowledge and Attitudes	Be committed to the teaching of science and the corresponding roles which are inescapably associated with such commitments.
Human Relations Skills	Be able to establish and maintain rapport with secondary age youngsters.
Planning Skills	Be able to design assignments which will provide for successful learning opportunities to groups of pupils with varied abilities and interests.
Instructional Skills	Be able to provide students with concrete, "hands-on" experiences that will lead to concept foundation.
Management Skills	Be capable of properly storing and maintaining science material and equipment.
Evaluation Skills	Be able to evaluate your own classroom behaviour or to secure such evaluation from others in order to make any appropriate changes in behaviour.

(Simpson and Brown, 1977:217)

An interesting result of this classification is the emphasis given to the last four items; items which are fundamental to curriculum development as outlined by Skilbeck (1975) in his important paper on school based responsibility for the curriculum.

Bybee (1978) also used a progressive focussing method called 'Q sort' in order to obtain a ranking of teacher skills thought to be important

in the work of the professional science teacher. The original lists of skills were derived from members of the Association for the Education of Teachers in Science (AETS). The rank order of skills required was:

(1) Adequate personal relations with students,
(2) Enthusiasm in working with students,
(3) Adequate teaching methods and class procedures,
(4) Knowledge of subject matter, and
(5) Adequate planning and organisation.

Similar research to that reported by Bybee (1978) has also been carried out with other science education groups including: in-service teachers, pre-service teachers in primary and secondary science courses, and high school teachers. These results are set out for comparison in Table 1. They show a very high degree of rank correlation. Personal qualities are viewed as the key dimensions of science teaching. It is important to realise that, although this was a ranking exercise, all of these skill areas were seen as important by the respondents. There is some merit in the argument that effective teaching in the sciences is more than the sum of the total categories suggested in this sorting process.

An analysis of the foregoing papers reveals some differences in emphasis, and also some common findings. Personal characteristics of teachers, their abilities in all aspects of curriculum development, and knowledge of key concepts and processes of science appear to be the common factors. With respect to this last category, Jungwirth and Dreyfus (1974) have provided a valuable contribution to the debate about what forms of science knowledge are valuable in making decisions in classrooms. They have divided interactions between teacher, student and science knowledge being classified into several types, namely situations which focus on:

(1) Science content (subject matter),
(2) Philosophy of science,
(3) Science as enquiry,
(4) The methodology of science teaching.

We are well aware of the transmission of knowledge about subject matter. However, the other types are more subtle. Examples of interactions based on (2), (3) and (4) appear below.

Table 1

Comparison of Rankings by Various Groups of Science Educators

Category	Science Educators		Students with Precollege Teaching Experience	Students with Precollege Teaching Experience	Elementary Science Methods Students	Secondary Science Methods Students	Teachers involved with In-Service Education
	Women N=29	Men N=143	N=158	N=14	N=80	N=79	N=106
Knowledge of Subject Matter	4	4	4	3	4	4	4
Adequate Personal Relations with Students	1	1	1	1	2	1	1
Adequate Planning and Organization	5	5	5	5	5	5	5
Enthusiasm in Working with Students	3	2	2	2	1	2	2
Adequate Teaching Methods and Class Procedures	2	3	3	4	3	3	3

After Bybee (1978)

(a) Situation Requiring Teacher Reaction Relating to Aspects of of the Philosophy of Science: A pupil states that "Plant etiolation is the result of the plant trying to reach the light". What would the teacher say to him? According to Jungwirth and Dreyfus (1974) a teacher in this situation should warn students against the use of anthropomorphic explanation. i.e., against the assignation of human characteristics to the plant's behaviour.

(b) Situation Calling for Teacher Reaction Related to Aspects of the Methodology of Science Enquiry: A pupil reports "I put a plant in the dark for several days. At the end of the period I tested the leaves for starch and did not find any. It follows that plants do not synthesise in the dark." What would the teacher say to him? According to Jungwirth and Dreyfus (1974), the teacher's reaction should be "How do you know?"

(c) Situation Requiring Adherence to the Principle of Science Teaching (the Philosophy of Teaching Science as Enquiry). A Year Nine Class is studying respiration and has just seen a comparative table showing the composition of inhaled versus enhaled air. One pupil draws the conclusion "nitrogen apparently serves as a catalyst in respiration since it enters and leaves the body unchanged". How should a teacher react? Jungwirth and Dreyfus (1974) suggest that, in this situation, the pupil's conclusion is in accordance with his level of scientific knowledge. There are experimental ways of determining whether nitrogen is essential for respiration, or else the student may be directed to the literature. Through these strategies the pupil should become aware of the 'nature of scientific enquiry'.

There is no doubt that many teachers already make distinctions between these categories in their classroom, but it is likely that others do not. The introduction of these dimensions to pre-service science teachers is a way of raising the consciousness of all teachers about the nature of science, and could lead to the improvement of science teaching in the classroom.

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Conclusion

From what has been written above, it is possible to identify the characteristics of the 'ideal' science teacher in broad terms. He/she must be a person who is skilled in his: knowledge of science concepts and his understanding of the nature of science. He should be able to develop effective curricula, is familiar with behaviour patterns of students, is highly motivated and has certain personal characteristics related to maturity and confidence as a human being. As Zoller and Watson (1974) have commented:

> "It is quite clear that prospective science teachers are expected to be admirable persons: wise, thoughtful, humane, mature, socially oriented and educated."

A key question for us is whether such 'superbeings' (Rosen, 1976) can be produced from our courses, and whether the present structure of programs being offered can help develop the characteristics of an effective science teacher which have been outlined in this discussion.

TRENDS IN PRESERVICE EDUCATION OF SCIENCE TEACHERS

Introduction

This section focusses on science teacher preparation and includes a framework for discussion, a synthesis of research findings and overviews, and a catalogue of recent developments. Most of the references are American, however there are also relevant studies in the Australian and British contexts. Extrapolation of American and British findings to the local scene appear to be justified because of the similarity in problems faced by teacher educators in the three countries, and also because of similar organisational patterns of schooling, teacher education programs and the general cultural milieux.

In the preceding sections, teacher effectiveness was considered, first at a general level and then as related to teaching the sciences. Whereas the emphasis at the general level was on appropriate classroom behaviour, the review of science educators' opinions about teaching suggested that an effective science teacher should possess certain knowledge, skills and personal qualities. The task of this section is to examine information which helps one to decide how a program of pre-service education should be created to develop these attributes in prospective science teachers.

The diagram in Figure 1 portrays a paradigm of some importance to this section of the discussion. Its importance lies in the schematic link between two phases of teacher behaviour; phase one, the acquisition of knowledge, skills and attitudes during preservice education, and phase two, the effectiveness of teachers in schools, in terms of the appropriate use of the attributes encountered in phase one.

It is important that we note the dependent variable(s) in phase one become the independent variable(s) in phase two. This paradigm has been used by Okey et al (1978) to consider research on teacher effectiveness, but it appears to have relevance as a more general paradigm for considering teacher behaviour in preservice education. A crucial issue is the interface between the two phases. This represents the trans-

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lation of acquired attributes from preservice education into real school situations. The approach to preservice education selected must take into account the need for effective translation across the interface. There is some evidence which suggests that vicarious experiences, that is, those which take place largely outside schools, may not be the most likely ones to enable students to 'cross the gap'.

It is now pertinent to review forms of teacher education in the light of the paradigm in Figure 1. Just how successful have various forms of teacher education been in encouraging the acquisition of appropriate knowledges, skills and attitudes in beginning teachers? This is taken up in the next section.

Developments in Preservice Courses

In a recent review of developments in science education, Craven (1977) presents an historical account of developments in science teacher preparation. He states that, in the 1950s, a major concern in the USA was to develop programs to offset the shortages in qualified science teachers. There was little examination of the quality of these programs until the early 1970s. Then, as a result of criticisms of some of the 'traditional' courses, new models of teacher preparation were initiated. These new models are characterised by:

(1) A shift from the dominant role of the university personnel with on-campus teacher education programs to a field based effort using supportive personnel from the public (state) schools.
(2) A greater cooperative venture and shared responsibility for teacher education among university and public school personnel.
(3) The opportunity for prospective teachers to become involved with school students early in their undergraduate programs, and
(4) A consideration of the humanistic movement in science education.

The major criticisms of more traditional programs are that:

(1) Beginning teachers are inadequately prepared in science

content to be effective. Lack of subject matter knowledge is a persistent problem recognised by administrators, cooperating teachers and science educators.

(2) They have not provided adequate models whereby teachers in training learn science by enquiry strategies similar to those they are expected to use in much of their teaching. Nor do the programs provide adequate models of integration of several disciplines or of science with other disciplines to adequately prepare students to teach the integrated courses that are being advocated. A desirable strategy would be to provide model inter-disciplinary courses as part of the teacher education program if, as it is widely assumed, teachers tend to teach as they have been taught.

(3) Education courses are irrelevant; there is a gap between theory and practice. Newton and Watson (1968) carried out a survey of recently graduated science teachers. The majority felt that the education component of their (traditional) courses were irrelevant to their future career. Other more recent studies, such as that of Fuller and Brown (1975) have reported similar findings.

(4) Recent graduates of science teacher programs do not know how to deal with problems in the 'real' world of teaching. In the schools, a most important problem for the beginning teacher is discipline and class control (Tisher, Fyfield and Taylor, 1979). Recent Australian research suggests that new science teachers perceive lack of advice about this aspect of teaching to be a major failing of preservice courses. When discussing the reactions of Macquarie University graduates to their program it was stated:

> The most consistent criticism by ex-students (of preservice courses) was levelled at the lack of grounding in classroom discipline and control methods. Typical statements included 'no mention of discipline methods', 'too much emphasis on middle class situations - far easier to teach a child who is willing to learn'.
>
> (Willings and Hermann, 1979:78)

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(5) Preservice science teachers are often provided with poor models of science teaching.

Studies of Horowitz (1968) and others show that the supervising teacher and the school setting have a profound impact on the beginning teacher. Fuller and Brown (1975) discuss studies which show that teachers changed their form of control from humanistic to dominating in a short time due to the conditions of the school in which teaching practice took place. Bush and Enemark (1975) have shown that teachers in training are subject to pressure to conform through the school's hidden 'teacher-education' program. Craven (1977) remarks that:

> it is evident that cooperating teachers should be models of effective science teaching, and that schools be supportive of student teachers as they try new things, some of which may be likely to fail.

(6) Those concerned with preparing science teachers do not know what is needed to prepare an effective science teacher.

This brings us full circle to the major problem; the link between preservice teacher education courses and the subsequent requirements of new teachers. We should take note of the limited amount of research in this field and, in addition, complement this with the opinions of experienced schoolmen and educators. Given these criticisms, what are some of the hallmarks of 'good' teacher education programs? Some suggestions appear below. They are based on reviews of science teacher educators who have contributed to recent ERIC documents.

(1) Education for a lifetime of learning. This has been identified as the prime affective component of a college program. This aspect is likely to be transmitted to students by college staff who act as models. Scholarship and a commitment to learning independently are the desired goals. There is also an element of responsibility on the student, for example,

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Hurd (1973) suggests that,

> we should begin by rejecting as early as possible students who are not really interested in a scholarly life.

He continues,

> a teaching candidate who... does not see the importance of spending at least three percent of his annual income on professional books, magazines and activities throughout his entire career is not a person we should encourage.
>
> (Hurd, 1973:517-518)

These are fine sentiments; what needs to be developed are the means by which we can predict whether or not beginning teachers have the desired approach to personal development during their initial training period or when it is at an end.

(2) Personalised competency-based programs. This has been discussed to some extent in the discourse on criticism of conventional programs. Craven (1977) argues for a select group of educators to set down criteria for effective science teaching. Further, he believes that there should be flexibility in criteria as they apply to teaching by different individuals and in different circumstances.

(3) Competence in the subject to be taught. There is a belief that an appropriate pre-service course should include both breadth and depth. In discussing methods of approach it has been stated that:

> College and university courses in the pre-service programs should be models of scientific enquiry as conceived by developers of curriculum materials such as Project Physics, BSCS, Chem Study and ESP.

Also,

> ...it is conceivable that learning the structure of scientific disciplines through enquiry strategies would provide the necessary preparation and predisposition for the prospective teacher to design and teach science courses tailored to the needs of his students.
>
> (Craven, 1977:39)

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(4) Interdisciplinary Studies. Craven (1977) believes that,

> A strong general education in science will continue to be vital in order to make science relevant for the student who has no interest in a science-related career. A series of interdisciplinary studies drawing from several disciplines in the arts and sciences could constitute an important aspect of the general education of both the prospective science teacher and the students that he will teach. Science-related social problems would be studied in depth. An up-to-date knowledge base would be stressed; value systems challenged; alternative solutions proposed; probable consequences inferred; and acceptable trade-offs considered. Teams of faculty members representing several disciplines would help to assure an adequate knowledge base and a valid examination of the issues and problems from various points of view. Students would be lead to a scholarly, value-laden, interdisciplinary study of topics that they would help to select. Science educators would join with science teachers, academic professors, other educators, and science teacher candidates to study problems and issues related to science teaching that are suggested by in-school experiences of the prospective teachers. These interdisciplinary studies would exemplify education in which teachers and students are partners in a teaching-learning team.

(5) Specialization in teaching and learning. Beginning teachers should possess a sound knowledge of curriculum aspects, including the ability to diagnose student needs, and to make science interesting and relevant to students with different aptitudes and interests. In particular, teachers in training should gain practice in the selection and adaptation of existing curriculum materials for use in different contexts.

(6) Cooperative (school-college) programs. Many writers suggest that close links should be forged between teacher preparation institutions and the schools in which pre-service teaching practice takes place. Control of pre-service education should be evenly distributed between both college and the schools.

The list above provides some guidelines for the outcome of a program of teacher education, the assumption being that a beginning teacher who has been exposed to study within these broad categories will become an effective teacher. The sixth point suggests that experience in the schools should be an essential component of a pre-service program. This would probably be agreed upon by all teacher educators. In the remainder of this section, the focus is on the ways in which programs undertaken by the tertiary institution could be arranged to take into account the characteristics listed above in points one to five.

First, at the most general level, two distinct and opposite approaches can be identified.

The first is commonly known as competency or performance based teacher education (CBTE or PBTE). CBTE programs have been implemented in many American teacher education institutions over the past decade. A CBTE program rests on the ability of those administering it to specify clearly in advance a list of characteristics that beginning teachers should possess at the conclusion of a course in teacher education. The resulting program should then provide students with the opportunity to acquire these characteristics. Adoption of CBTE by colleges has been brought about partly from pressure exerted by teacher accreditation boards, and has also been influenced by those who believe there should be higher specification of the content of teacher education courses. There are five essential elements of CBTE:

(1) Teaching competencies should be derived from the expected roles teachers will play in the schools, and these competencies should be specified in behavioural terms,

(2) Assessment criteria are competency based, mastery levels are specified, and are made public,

(3) Assessment requires performance as prime evidence and takes student knowledge into account,

(4) The rate of progress of a student depends on demonstrated competency, and

(5) The instructional program facilitates development and evaluation of specific competencies.

A superficial consideration of CBTE might lead to the conclusion that it is a panacea for the problems of teacher education. However, there are critics of this approach who have identified four major areas of concern:

(1) Identification of Appropriate Generalisable Skills.
Some teacher educators believe that there is not sufficient overlap in teaching in different subject areas to enable a set of common skills to be identified. There is also an underlying objection by some to the 'reduction' of teaching from an art to a set of discreet definable skills which could serve as the basis for a teacher education program.

(2) Superficiality of Approach.
Some argue that preservice teachers must accommodate the set of norms associated with schooling into their system of beliefs. These critics accept that student teachers must learn some of the skills associated with classroom management, curriculum, etc., but they question whether a program of CBTE is the most appropriate method by which these skills can be internalized during preservice education. They distinguish between a student being able to show that he has mastered a skill and the student possessing the attitude to use that skill in his teaching.

(3) Transferability.
Objections to CBTE suggest that it is artificial in that it attempts to promote the acquisition of discreet skills, one at a time. In real school situation, critics argue that the teacher operates in a milieu in which many skills need to be used almost simultaneously. They argue that CBTE programs do not help here.

(4) Lack of Evidence Connecting CBTE with Student Learning.
Up till now, there has been a lack of research linking CBTE with school student outcomes. However, this seems to be due to the lack of appropriate research in this

area and not to CBTE per se.

When examining the teaching of the sciences, one can identify clearly preferred methods of approach which have been promoted over the past two decades. These arise out of the nature of the subjects and hence it appears possible to overcome the first of these objections. Clearly, the second and third are linked, and it appears now that CBTE must be associated with extensive school practice if the objections contained in these points are to be countered. From an experimental point of view, there seems to be some merit in enabling students to practise some of the skills associated with science teaching before they actually go to teach as apprentices in schools. (This is the basis of the microteaching courses at the University of Sydney.) There needs to be work done in identifying these skills, and then more research carried out to see whether they do, in fact, assist beginning teachers in their formative years in schools.

The second major approach is described as humanist. This approach has been fostered by Comb (1972a, 1972b) and is predicated on the following viewpoints:

(1) The production of an effective teacher is a highly personal matter, dependent primarily on the development of an appropriate system of beliefs,
(2) The production of an effective teacher must be regarded as a problem in becoming,
(3) The problem of becoming must start from security and acceptance,
(4) Effective teacher education must concentrate on meanings rather than behaviour,
(5) If sensitivity and empathy are prime characteristics of effective helpers, and if behaviour is the product of perception, teacher education programs must shift their main concerns from objectivity to subjectivity.

Those who do not agree with this approach criticize the lack of explicitness in describing how such internal changes might come about. This seems to be a valid question, and one could argue that

humanist theorists should link experiences associated with teaching and learning to the achievement of teacher self potential. A difficulty in conceptualizing humanist preservice courses in the sciences lies in this area, in a specification of the methods which should be used to educate prospective teachers. This lack of direction pervades the criticism of the humanist approach:

> ...we are describing enculturation rather than teacher education and find ourselves with no justification for creating the institution of teacher education for the job has been completed...(there is) no operational description of the educational product, no way to determine how to arrive at these states, and no way to assess when we have achieved them. (Koran, 1974:58)

A possible mode of operation in using the humanist approach has been suggested recently by Fenstermacher (1978). His alternative to the skills approach of CBTE is to confront students with important information and research findings which are related to schooling. A program of this nature would be characterised by the ability and willingness of the preservice teachers concerned to use these data to transform their belief systems. However, there is still the need for these teachers to manifest these belief systems in school practice. Clearly, contact with schools is an integral part of all pre-service programs, to illuminate and exemplify theory presented in this way.

It has already been stated that the CBTE and humanist approaches illustrate the extreme ends of the spectrum regarding the degree of structure in pre-service courses. Whereas CBTE places the emphasis on behaviour, the humanist tradition places the emphasis on commitment. In looking for a paradigm which combine elements of both approaches a recent paper by Bruce and Miller (1976) contains some interesting proposals. Referring particularly to the area of school science, these writers view teaching as,

> ...a process of integration of cognitive, affective (stylistic) and technical components into a series of activities aimed at the attainment of certain learning goals. Cognitive components include the teacher's knowledge of the subject area, knowledge of adolescents, and understandings of those aspects of methodology that can be taught as information. Affective components include those things that make for style, individual personality traits, feelings

> toward children, feelings about the educational system, feelings about the subject area, and behavioural patterns. Technical components include manipulative things which can be taught as parts of the process such as the use of questions, establishment of learning goals, and the use of instructional materials. The ways in which these components are put together by the teacher, and interact with each other produces the teaching/learning situation in which the teacher attempts to meet the learning goals confronting students.[1] (Bruce and Miller, 1976:72)

The emphasis on an integrative approach of knowledge, skills and attitudes has implication for science teacher education. A way of conceptualising the development of student teachers is to assist them to progress through several levels of goal attainment. Bruce and Miller (1976) offer the paradigm illustrated in Figure 2 for this development.

The emphasis in this figure is on the development required in order for students to progress towards a mature teaching style. Within the technical component, there is a set of hierarchical boxes, each box subsumes and organises objects contained in the lower boxes. According to this paradigm the student would progress from classroom skill acquisition to a mature teaching style. This would include an ability to develop and implement school based curricula if it was applied in an Australian context.

An important aspect for consideration is the inclusion of the cognitive and affective aspects and their interactions (IXN) at every stage of the students' development. The more complex the task set for the teacher the more complex is the interaction amongst cognitive, affective and technical areas. For example, at the lowest level, a skill acquisition may mean the use of a small element of subject matter (cognitive) using a single method of presentation presented by an instructor (affective). At the extended strategy level, for example, in the production of a learning sequence with long range goals, the cognitive area must contribute a consistent view of the subject area as a whole so that the learning sequence has continuity towards these goals rather than existing as a set of disconnected pieces. The affective area is also hierarchical. For example, in

[1] my emphasis.

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the choice of appropriate methods of approach which are suitable for the achievement of the long term goals, the appropriateness of a particular method may require the teacher to select an approach which is at variance with his 'natural' style.[2] This requires a teacher to develop an awareness to adopt other approaches when a situation calls for them. This may require a reanalysis of teacher-student roles. For example, the selection of a particular method based on a subconscious distrust of the students' ability to handle certain apparatus could have important deleterious effects on the goals of a long range program which are not evident when interest is focussed on the shorter range.

The importance of cognitive aspects of teacher education in science has already been considered in an earlier section. From the limited research it is suggested that students need to have met and understood key concepts in the sciences in order to be able to plan sequences of work. This research is in accordance with the Bruce and Miller model. If we expect our teachers to be school based curriculum developers we need to provide them with courses in the subject areas they will come across in their teaching. Within these courses, it is necessary to stress the 'big ideas' which underly different branches of science. Perhaps a first step would be to consider whether there are differences in the 'big ideas' in the traditional branches of science as they are taught at the tertiary level.

A further consideration of this paradigms is the extent to which student teachers can progress up the hierarchy of skills, knowledge and attitudes illustrated in Figure Two. Bruce and Miller are pessimistic about the degree of progression towards a mature teaching style in typical American pre-service courses:

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[2] There has been a distinction made between teaching styles and teaching methods (Martinez-Brawley, 1977). A method can be thought of as an approach, a learnable way of doing things, whereas a style can be thought of as a reflection of a person's personality. A teacher can employ a range of methods, but his style of teaching becomes part of a characteristic mode of behaviour.

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> The teaching act performed by the beginning teacher cannot realistically be viewed as the end product of teacher education. It is a stage in the teacher's development. Teacher education, carried on in the accustomed fashion can produce, at best, apt apprentices. A planned component of teacher education beyond the point of entry (to the profession) is long overdue. (Bruce and Miller, 1976:72)

Those who are concerned with the development of more effective teachers may question programs which produce 'at best, apt apprentices'. There may be a case for more time to be devoted to activities within which teachers could develop the competencies set out in the paradigm. Even if this could be achieved, the general thrust of the above quotation is still important. Accordingly, teacher education institutions must consider seriously the creation of graduate courses in science education for experienced teachers.

New Programs of Science Teacher Preparation

Earlier in this article, it was mentioned that there had been some new approaches to teacher education in the USA, as a reaction to criticisms of older style programs. In the area of science teacher preparation the Iowa Up-Step Program is an example of an innovative course. It is an integrated four year program, and the relative time allocated to each of the three major strands can be gauged from Figure 3. The approach used in this program is based on the notion that the development of teacher self concept is a prime goal of the pre-service program. It is argued that performance as a teacher in schools is strongly dependent on the beginner's opinion of self. One method used in the course is to conduct field-based clinical experiences involving sophomore, junior and senior students (students in the 2nd, 3rd and final years). Based on experiences in schools, the following student-teaching skills are developed: self instruction for school pupils, individualised instruction, case studies of pupils, studies of intellectual levels, teaching styles, classroom communication and curriculum development.

A further important aspect of UPSTEP is that it has undergone intensive evaluation. Pizzini (1976) carried out a study to determine whether

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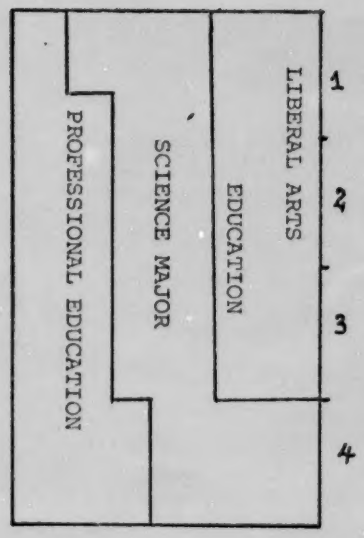

Year

1 (Freshmen)

2 (Sophomore)

3 (Junior)

4 (Senior)

Figure 3. Recommended IOWA Up-Step Sequence of Science Teacher Education. (After Lunetta , 1975)

the Iowa-Up-Step program developed more positive-self concept among the participants. Using a 12 variable package called the Tennessee Self Concept Scale, Pizzini (1976) discovered significant gain scores on 10 of the 12 variables by those in the experimental group. A 'control' group, who undertook a more traditional teacher education program showed significant gain on only one of the 12 scales. Pizzini suggests that the implications of this study are that changes to pre-service programs should be considered if development of self is considered to be an important outcome. These include:

(1) Involving prospective teachers in professional training at an early stage of the teacher education program,
(2) Providing flexibility in the course to allow prospective teachers to find their best way of teaching.
(3) Allowing prospective teachers to have input to course decision making,
(4) Providing for group discussions of the experience, and
(5) Providing an atmosphere conducive to exposing ideas and discovering that learning is a matter of personal exploration and discovery.

We see here the use of the approach suggested by Fenstermacher (1977) which was outlined earlier in this review. There is some tentative evidence of a link between self concept and effective teaching (Coulter and Elsworth, 1977, Coulter, 1980). Thus, it could be argued that courses designed to develop self concept are valuable in preparing good teachers.

Anderson (1975) provides us with an alternative model, one of core plus options or mini courses which has evolved at Indiana University. This program was developed because a more traditional course was considered by the faculty concerned to be unsatisfactory. The traditional course consisted of the units: Introduction to Teaching, Educational Psychology, Methods of Science, and Principles of Secondary Education. The new course takes an applied educational studies approach. Its broad objectives are to:

(1) Create opportunities for early and continuous field (school) experiences, and to

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(2) Develop reliable competency based learning experiences for pre-service teachers.

The course has the following administrative features:

(1) An across-discipline team of the education faculty concerned,
(2) The involvement of secondary school teachers as planners, developers, evaluators and instructors,
(3) An advisory board of secondary school teachers, and
(4) The involvement of students, members of review faculties of the university and teachers in advisory capacities when needed. Within the core there are four major sections:
    (i) 'Myself as a Teacher'
    (ii) Observations of teaching and learning
    (iii) Curriculum Developments and Science Teaching
    (iv) Teaching Practice, Seminars on Problems in the schools, Principles of Secondary Education (mandated by the State).

The 30-mini courses have been designed to cater for individual differences of 'interest, ability and experiential background of our students at a lower cost than traditional instruction'. They are self instructional and may be completed by students in their own time.

This program is attractive in its applied studies approach, which concentrates on the problems beginning teachers face in the classroom. In addition, there is a flexibility engendered by the availability of alternative mini courses. As yet, no evaluative documents have been published.

Research Findings Relating to Science Teacher Preparation

In this penultimate section some research related to these points is introduced using the Bruce and Miller (1976) paradigm as a basis for discussion. As indicated earlier, they suggested that preservice teacher development should take place in three primary areas:

(1) Cognitive - knowledge of the content of science,
(2) Skills - curriculum development attributes, and
(3) Affective - development of personal traits

Within these three areas, there is information available about certain aspects of teacher education. These are:

(1)	Cognitive	(a) processes of science
(2)	Skills	(a) interaction analysis
		(b) questioning and pausing
(3)	Affective	(a) interpersonal skills
		(b) attitudes to science and science teaching

(1) Cognitive - Processes of Science.

In addition to what might be termed 'academic' work in subject areas such as biology and chemistry, there have been attempts, in teacher education courses, to allow students to examine the nature of science through programs which are often based on large scale curriculum projects. An alternative approach has been to construct specific sequences designed to allow future teachers to work in a laboratory based setting.

One impressive example of these activities has recently been reported by Yeany et al (1978). He used an instrument called the Data Processing Observation Guide (DPOG), which is shown in Figure 4. This allows student teachers to see clearly the interactions between students, teachers and subject matter. Using a data sheet based on this paradigm, students can analyse lessons and estimate the proportion of time spent on different types of activities. Yeany (1978) has used this scheme to orient student teachers towards the use of process skills in their teaching.

Another approach to an examination of the process of science has been outlined by Bicak (1975). This program has three major elements. Preservice science teachers take part in the:

(i) Identification of Problems and Designing an Investigation - classroom and field identification of problems to be investigated and the subsequent designing of experiments and/or observations based on the problem;

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(ii) Examination of Existing Investigation - an in depth examination of an investigation, past and present which includes good and poor illustrations of science, and the

(iii) Examination of Representative Curricular Activities - carrying out representative activities in curricula which deal with science as investigation.

The essence of the program is investigation and is predicated on the assumption that, if the 'method' lecturer uses enquiry methods, the investigative approach develops more informal, personal type of relationship within his classes, then prospective teachers in preservice programs will have this kind of science instruction as a model. Hopefully, they in turn will encourage students in secondary school to learn by doing, by investigating, by discovering, and by inquiring.

(2a) Skills - Interaction Analysis.

The study of student-teacher interaction in the classroom as a method of determining teacher effectiveness was introduced in the first part of the report. In the previous section, an example of a scheme for studying such interactions in science classes was outlined. This scheme appears to have relevance for interactions found in science classrooms, whereas the more general schemes, such as those constructed by Flanders, are less pertinent. Rowe (1977) is critical of the general schemes because of the inappropriateness of some of the categories for science teaching. For example, in the Flanders scheme, long wait times before students respond are considered undersirable. Rowe believes that, in science, long wait times are consistent with appropriate student behaviour, in that they are associated with the risks students take in participating in enquiry methods of instruction.

A method of observation simpler than that outlined above by Yeany (1978) has been proposed by Bratt (1975). Using an audio cassette replay of science lessons, students analyse the nature of the interaction between school pupils and teachers as a function of time. Use is made of the categories: Teacher Talk, Student Talk and Silence. Another self evaluation

activity undertaken in this program is to determine the percentages of convergent and divergent questioning carried out by the teacher.

(2b) Skills - Pausing and Questioning.

Pausing - In studies conducted over several years, Rowe (1977) found that inquiry related behaviours of school students could be improved if teachers increased the time they waited for a student to reply to a question and lengthened the period of a pause after the student makes a reply. When this pause was lengthened (from a typical value of about one second to three seconds), it was found that: the length of students' responses increased, the incidence of students' speculative thinking increased there was an increase in the number of inferences made by students which were supported by evidence, and children asked more questions and suggested more experiments to obtain answers.

Rowe devised a scheme which was intended to promote pause time. Microteaching techniques were used which involved feedback in small groups. Seventy percent of course participants 'achieved the criterion' a figure which Rowe considered to be unsatisfactory. She suggests other alternatives which could be tried.

Questioning - Rowe has reviewed several recent studies in this area. One, by Blosser (1973), found that preservice students who received training on question-asking techniques showed more varied strategies than did students who had not had special training. Those who seemed to benefit most from the training were those who received it just prior to and during teaching practice. Also, when cooperating teachers also modelled the desired techniques, the probability that the student would also use the appropriate techniques was higher. This study emphasises the important role of the supervising teacher as an exemplar for new teachers. Blosser's (1973) study showed that development of questioning skill was not associated with intelligence, sex or personality type.

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Rowe, in her summary of research on questioning, suggests that the examination of one aspect of teacher behaviour in isolation from others which are likely to be associated with it, may not prove to be fruitful. She believes that questioning patterns, pausing and reward may be related. For example, for teachers to foster inquiry, it might be that teachers need to ask fewer but more thought provoking questions, and that students be given more time to think and make more incisive responses.

We have some excellent suggestions for the implementation of sessions devoted to questioning in the STEP and ASTEP materials. Also Lamb (1977) provided information about a module designed to increase the range of cognitive questions asked by student teachers. Those taking the module were shown to ask a wider range of questions after they had undertaken the program.

(3a) Affective - Interpersonal Skills.

An important recent trend in teacher education is the recognition that personality factors affect the way teachers perform in the classroom. Discussion related to selection of teachers has, in enlightened quarters, given way to questions about matching of individuals to particular educational contexts. According to the work of Myers (1972) different personality types may respond to various forms of teacher education.

That there are variations in personality traits among prospective teachers leads one to postulate that there may be variations between teachers in their natural approach to classroom teaching. Gordon and Gross (1978) concluded an experiment with pre-service teachers (of mathematics) which investigated the relationships between approach and the following personality aspects: conceptual level (CL) and field dependence-independence. Conceptual level was a measure of productive thinking ability - the ability of teachers to produce alternative ways of teaching course concepts. Field dependence-interdependence (FDI) is an indication of propensity for social interaction on the part of the individual. Field independent persons are more attracted to occupations

where social interaction is limited and analytical skills are required.

In this study it was shown that there were significant differences in approach, measured on an inductive/deductive dimension between students of high and low CL, and between students of high and low field dependence. Students of high CL and students of high field dependence preferred the inductive method.

This study has at least two implication for teacher education. The first is to monitor these aspects of personality in order to create appropriate experiences in college programs. The second is to consider if and how these personality variables can be modified in order that teachers can adopt a range of teaching methods.

(3b) Affective - Attitudes towards science and science teaching. Associated with the development of enquiry methods in science teaching, there has been an attempt to influence teachers to adopt methods of teaching sympathetic to these methods. There is evidence which suggests that school factors, lack of knowledge of the materials involved and lack of support from outside the school are important barriers to the adoption of these new approaches. In addition, it is apparent that the attitude of teachers toward science and toward teaching in a manner sympathetic to the enquiry approach also influence its adoption. Programs in perservice science teacher education have attempted to modify the views of preservice teachers toward enquiry approaches. There have also been attempts to link personality and attitude variables to teaching methods. Concern for attitude change has been predicated on the views expressed by those such as Bybee and Deter and Hounsell that teachers should show enthusiasm and caring for the subject.

Studies of the effects of programs designed to change prospective secondary teachers attitudes to science or to science teaching have been reported by several workers including Bruce (1969), Bollen (1973) and Riley (1975).

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It is clear that research on the effects of attitudes toward science/ science teaching are ambiguous: we can say that we know little about the effects of attempts to change the way individuals view these aspects. There is some evidence that the attitude of an individual toward science teaching is related to his cognitive development in the area to be taught - perhaps this is tempered by underlying psychological traits. One must also question whether relatively short courses conducted during a professional segment of a four year tertiary course can affect the views of a student who has also undergone an intensive study in a discipline area of science which has been taught in traditional ways.

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Introduction

Compared to the review of developments in science education this review of mathematics education is relatively short. There are two reasons for this. The first is that many of the general aspects were introduced in the science education review and do not need to be restated here. The second is that the extent of mathematics education literature which emerged from the computer search was far less than that which emerged for science education.

Apart from these aspects, the layout for this section is similar to that for science education. Some general comments are made regarding mathematics in secondary schools and its relation to teacher education; these are followed by a subsection concerned with research on mathematics teaching. Finally, a more specific discussion on pre-service teacher education is outlined which includes examples of innovative pre-service programs.

Important curriculum development questions posed most lucidly by Skilbeck (1975) appear to be a suitable framework for a beginning discussion of teacher effectiveness in mathematics and the implications for the education of teachers in this discipline area. Skilbeck's (1975) proposals can be reduced to five key questions:

(1) Why shall I teach (it)?
(2) What shall I teach?
(3) How shall I teach?
(4) What are the local conditions which affect these considerations? and,
(5) How do I know whether or not I am successful?

With the exception of question four, most American and English mathematics educators use this framework to discuss aspects of teaching and learning in mathematics. The lack of attention to question four is due to the fact that, in these countries, decisions about mathematics curricula have not been taken at the school level. Hence, consider-

ations which would fall under the fourth heading do not arise. An example of this is Begle's (1969) scheme for classifying areas of research in mathematics education. These are:

(1) the ultimate objectives of mathematics education,
(2) order and sequencing of topics,
(3) methods of approach in the classroom, and
(4) the capabilities of the learner.

These areas seem to be suitable for classifying the major thrust of journal articles pertaining to mathematics education, not only those devoted to research. An example of an article which could be classified under (1) is that by Bell (1974). He was obviously stimulated by the need to specify the knowledge which would be necessary to ensure a basic mathematics literacy for citizens living in an advanced western technological society. Arising from these perceived needs, a list of the processes and content was drawn up which could form the basis of a secondary school mathematics program; it is included as Appendix One.

Other studies fit into different categories. Watson (1971) is concerned with areas (2) and (3) and the interaction between them. He believes that mathematics teachers should be able to see the difference between methods and content. He has a vision of school mathematics as an approach which cultivates the ability of students to apply mathematical arguments to new situations rather than one which emphasises the accumulation of mathematical knowledge.

A consistent feature of the literature is the concern for mathematics teachers to distinguish between the underlying logic of mathematics as a discipline and a knowledge of routine mathematical techniques. Peter Galbraith (1977) talks about the 'spirit, methods and creative processes' of mathematics which need to be understood by aspiring mathematics teachers. Galbraith expects such teachers to value the processes of mathematics rather than value the mastery of routine techniques. This is a sentiment we have encountered in the literature devoted to trends in science education.

Much of the discussion regarding maths education is concerned with the third of Begles (1969) categories namely, methods of approach within the classroom. The basis for these discussions is a framework in which the teacher, the student and an organised body of knowledge are the three key elements. There is a strong strand running through these discussions which assumes a link between the nature of mathematics and the ways in which mathematics should be taught. This implies that the modal form of mathematics instruction may be different from the modal form of, say, social studies instruction (there is some evidence for this, outlined later).

Some Empirical Findings in Mathematics Education

Empirical studies of mathematics teaching have led to the conclusion that interactions in the classroom can be divided into two broad types. One type is content bound; the other content free. Content bound strategies are concerned with the interaction of the teacher with the subject matter; general strategies are concerned with the interaction of the teacher with students. Smith (1976a) has identified the nature of interactions which appear to be derived from the nature of mathematics. In describing a series of studies which were based on observations of mathematics classroom activities, he states:

> After trying a number of approaches, we finally broke the (classroom) discourse into units called ventures. We used as a criterion of a venture that the discourse leads to a meaningful object, that it has import. We thus classified the ventures in accordance with the 'meaningful objects' embedded in them. This procedure resulted in a number of different kinds of ventures; concept ventures, appreciation ventures, cause-effect ventures, reason ventures, value ventures, rules ventures, procedural ventures, and particular or factual ventures. (Smith, 1976a:31)

Smith (1976a) identified the classroom interactions which were associated with the substance of each of these kinds of ventures, not only in mathematics teaching, but also in teaching content related to other disciplines. He goes on to say that the interactions within mathematics instruction varied according to the venture examined.

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Also:

> When a number of ventures of the same type are analysed across disciplines, it turns out that each type has more than one pattern of moves depending on the discipline... In one view, therefore, one does not speak of a strategy of teaching in general, but of strategies appropriate to each teachable object in each discipline. (Smith, 1976a:32)

The implications of these findings are twofold. First, it appears that a teacher has a greater chance of improving cognitive achievement if he or she is aware of the types of content: concepts, facts, principles, etc., being taught. This is largely the concern of the 'academic' course constructors in programs for prospective teachers. Second, the beginning teacher must become aware of the various logical operations; describing, comparing, classifying, explaining, generalising,abstracting, etc., which are used in the manipulation of the types of content listed above. Because teachers often do not possess this kind of understanding or, in many cases, have not had the opportunity to categorise their activities in this way, they handle subject matter in ways that lead to vagueness and confusion in school students. A comprehensive overview of 'traditional content' in terms of the dimensions introduced by Smith (1976a) and listed above, may go some of the way towards alleviating problems encountered by Galbraith (1977) in his survey of mathematics education programs. All prospective maths teachers, regardless of their 'natural ability' should profit from being made aware of these types of patterns in their teaching. Creation of preservice courses committed to assisting students make links between content and instruction would need the cooperation of a all staff concerned, by the 'academic' or 'method' specialists.

The work of Smith reported above, and others in the USA and in Australia has given us some insight into aspects of mathematics education which are centred in the classroom. Unfortunately, most of this research has used the elementary school setting. Some of the recent research which has taken place in secondary schools is now summarised; most of the studies reported have been reviewed recently by Marilyn Sudyam (1976). These studies have been classified into six categories, according to their primary focus. There is, however, some overlap

between categories in some instances.

(1) Research on Ability Levels.

Strickmeier (1971) attempted to (a) describe and compare patterns of teachers' verbal behaviors in seventh-grade mathematics classes grouped by ability and (b) determine if seventh-grade mathematics teachers have different perceptions of their verbal behaviors and different expectations of student behaviors for classes of different ability levels. Teachers completed a questionnaire concerning their expectations of behavior within each class. He observed each teacher three times with a high-ability class and three times with a low-ability class.

Analysis of the data revealed that the teachers did have different perceptions and expectations for the classes of different ability levels. But despite these differing perceptions and expectations, teachers' behaviors were not different for the classes of different ability levels.

Kester (1969) found that seventh-grade teachers communicated with their allegedly bright pupils in a more friendly, encouraging, accepting manner. As the pupils' positive communication to the teacher increased, the teachers' communication to the pupils tended to be positive. Teachers also spent more time communicating with them. Nevertheless, pupil achievement was not significantly affected by the extent of interaction.

(2) Moves and Strategies.

Fey (1969) developed an instrument to describe both pedagogically and mathematically significant components of teacher-student interaction. Lesson transcripts were partitioned into a sequence of moves which were then described according to source; pedagogical purpose (structuring, soliciting, responding, or reacting); duration; mathematical content; mathematical activity (developing, examining or applying a mathematical system); and logical process

(analytic, factual, evaluative,or justifying). He found that: (a) each teacher spoke more than all of his students; (b) each teacher dominated the pedagogical functions of structuring (80 per cent of these moves), soliciting (95 per cent), and reacting (85 per cent), (c) over 50 per cent of all moves were statements or questions of fact , 25 per cent were evaluations, and the remaining moves were divided between justifying and analytic process; (d) content emphasis in all classes followed closely the sequence of the textbook chapter being studied; and (e) teacher influence in shaping the direction varied from class to class, but the difference was primarily one of degree than kind.

Stilwell (1968) studied the behavior of twelve secondary teachers during problem-solving activities in a geometry classroom. A sixteen-category instrument was developed, with ten categories for teacher-talk, four for student-talk, one for structured silence, and one for non-classifiable activity. Analysis of the data showed the following: (a) teacher-talk consumed approximately three times as much time as student-talk; (b) less than three per cent of all time in problem-solving involved the activity described as "method for solving a problem"; (c) approximately eight per cent of all time was coded as structured silence; (d) looking back at the solution or looking ahead to its implications consumed approximately seven per cent of the time; (e) behaviors in only three of the twelve classes observed differed significantly when engaged in review or in introduction of new content.

(3) Logic of Language Patterns.

Gregory's (1972) major objective was to determine the relationship between the frequency of use of the language of logic by mathematics teachers and their seventh-grade students' reasoning ability. He audiotaped each of twenty teachers' classes five times and administered a reasoning test to students at the beginning and end of a semester. The teachers were ranked on the basis of analysis of the frequency of their conditional moves, that is, how often they used "if-then" language in their

teaching. Students of teachers who used such language more frequently did better than students of teachers who made fewer such statements. Thus teachers, through the use of logical language in a variety of situations, apparently helped students to develop greater achievement in the aspect of logic considered.

(4) Questioning.

Meckes (1972) studied teacher-pupil interaction and teachers' questioning patterns for mathematics. A tape recording was made of one class session conducted by each of 100 teachers. Ten-minute segments of each tape were analyzed, and all teachers' questions were transcribed from the 100 tapes and classified into one of seven categories in the Taxonomy of Mathematical Abilities. Meckes stated:

> The results obtained from the Flanders Interaction Analysis appear to indicate that the role of the mathematics teacher has not changed from that of giving information to that of guiding learning experiences. This conclusion was supported by the following evidence: The teacher spent 61.5 per cent of the time talking. Direct influence accounted for 50.2 per cent of the teacher talk. Although indirect influence amounted to 49.8 per cent of the teacher talk, the largest portion of this was in the questioning category. Since most of these questions were very narrow, they provided little opportunity for students to express their own ideas.
>
> Although one of the primary objectives of new mathematics is to foster a spirit of inquiry and to develop creativity, only .5 per cent of the total questions were placed in the synthesis category. The two low cognitive level categories accounted for 79.5 per cent of the questions asked.

Friedman (1973) attempted to develop a system that would describe the extent to which teachers seek two important goals of a geometry course: eliciting high levels of student thought and learning the nature of proof. He also investigated the relationship between a teacher's questioning behavior and the performance of his students on a test designed to assess understanding of the nature of proof and the ability to think on various intellectual levels.

Thirty-five lessons taught by 15 teachers were tape-recorded as a geometry theorem was being taught. The median per cent of questions at the memory level was 23, considerably less than the percentage typically asked by teachers of other subjects. Comprehension questions were asked more frequently than other levels of questions; the median was 56 per cent. The median per cent of application questions was 18. Of 1841 questions asked, only four were higher-level questions, and only twenty involved the nature of proof.

The frequency of the application questions a teacher asked in class was positively associated with student performance on test items at the application level. For the other types of questions, however, the number of questions a teacher asked appeared to have no clear relationship to student performace on test items of the same cognitive level.

Training for questioning.

In a study with 30 science and mathematics teachers, Adhikary (1973) gave the experimental group an instructional program requiring the students to work through a programmed instruction unit on classifying teacher questions, discussing the use of different types of questions, writing questions in lesson planning, and discussing reasons why students do not answer teachers' questions. The teachers' question-asking behavior was changed following this instruction. They used more convergent, divergent, and evaluative questions, and fewer cognitive-memory and managerial questions than did those who had not had the instruction.

Nisbet (1974) used microteaching with audiotaping to help secondary mathematics teachers significantly increase their percentage of use of application and analysis questions.

Flake (1974) explored the feasibility of using interactive computer simulations to sensitize preservice secondary mathematics teachers to various questioning strategies, Polya's approach to problem solving, and a simplified learning theory. Nineteen of 25 students increased their behavior of modeling the prescribed problem-solving strategy; 22 demonstrated an increase in going beyond the first responses of a student.

(5) Content and Approach.

Kysilka (1970) observed 24 teachers (six each in eight-and eleventh-grade mathematics and social studies) four times. Among the findings were:

(1) Mathematics teachers asked more convergent and fewer divergent questions, used more procedural-positive questions, and made more directing and describing statements than did social studies teachers.

(2) Mathematics teachers talked significantly more than did social studies teachers.

(3) The proportion of pupil-initiated statements to teacher statements was significantly greater in social studies classes than in mathematics classes.

Hawkins and Taylor (1972), in Australia, also carried out a study which compared the ways teachers handled the teaching of different subjects, in this case the subjects were mathematics, English and social studies. This study was, however, conducted in primary schools (Grade IV). The study focussed on teacher responses to student questions. It was found that the teaching of mathematics involved greater use of 'corrective informative' than did the teaching of social studies; there was also far more use of probing techniques in mathematics than in English, and less use of procedures which tended to extend an interaction between student and teacher in mathematics than in social studies.

(6) Use of Nonexamples and Counterexamples.

First, Henderson's (1967) definitions:

Nonexample: an object which is not a member of the referent set (that is, not an example) is designated. Usually this move is employed when experience has shown that students make errors based on not knowing certain necessary conditions.

Counterexample: an object is named (or otherwise designated) that falsifies a generalization purporting to characterise the members of the referent set. This move is used after a characterising move and is never the first move in a concept venture. It is often used to enable to the student to correct a misconception

Shumway (1971) designed a study to determine whether an extensive treatment of nonexamples in the development of certain mathematical concepts in grade 8 would result in significant differences in mean scores on tests of (a) general mathematics achievement, (b) specific mathematics achievement, (c) inductive reasoning, (d) syllogistic reasoning, (e) reading mathematical definitions, and (f) tendency to overgeneralize. The study was conducted for 65 class periods with 84 students in four classes; content included quadrilaterals, exponents, and operations. The experimental treatment contained an equal number of positive examples and nonexamples. The control treatment contained only positive examples. The use of nonexamples was found to have a significant effect on the students' tendency to overgeneralize the properties of operations.

Shumway (1974), using Computer Assisted Instruction as the instructional mode, has also found that the use of nonexamples as well as positive instances (examples) resulted in higher achievement than the use of positive instances (examples) alone.

(7) Mastery learning.

Other researchers have contributed to an understanding of the way mathematics teachers carry out their tasks. The theoretical advances in Mastery Learning by Carroll (1963), Bloom (1968) and others have provided impetus for experimental studies of the procedure. At the time at which Carroll (1963) suggested that almost all students could attain the same level of achievement if given sufficient instruction, the American School Mathematics Study Group was organising an experiment to test this hypothesis.

This experiment involved two groups of experimental students and two corresponding groups of control students. The first experimental group consisted of students entering seventh grade (and thus between 12 and 13 years of age) who were between the 25th and 50th percentile in ability, whether measured by a standard IQ test or by a standard mathematics achievement test. The other

experimental groups consisted of students in the same ability range who were entering the ninth grade. The control groups, which were selected a year later, consisted of students entering seventh or ninth grade who were between the 50th and 75th percentile in ability.

Both the experimental and the control seventh grade students followed the same mathematics curriculum and used the same text prepared by SMSG. Similarly, the experimental and the control ninth grade students followed the same mathematics program and used the same SMSG algebra text.

What was different was that the experimental groups were given two school years to study the material which the control group studied for the usual one school year. A battery of tests was administered at the end of the experiment. Analysis of the test results showed that the seventh grade experimental students performed almost, but not quite, as well as the control students on this battery. Analysis of covariance using scores from a battery of pretests strongly indicated that the experimental students had learned considerably more, given two years, than they would have if they had only the usual one year. At the 9th grade level the results were in the other direction. The experimental students outscored the control students on the final battery of tests.

Here is a case then where students of below average ability were able to reach about the same level of achievement as students of above average ability as a result of an increase in the amount of instruction provided them. Begle (1969) carried out a similar experiment. In his own words,

> A very small topic in mathematics, completely new to the students was used and was taught for one, two, or three days. In the longer teaching sessions, no new ideas were introduced, but there was time for a wider variety of illustrations of ideas introduced and for more student discussion and questioning than was possible in the shorter sessions.

On the basis of a test of arithmetic reasoning, the students were grouped into three ability levels - low, medium and high. The average scores on a post-test were not significantly different along any of the three diagonals leading from lower left to upper right.

	1 day	2 days	3 days
Low Ability			
Medium Ability			
High Ability			

This is another example which illustrates that time could well replace student IQ as the basic variable in predicting achievement. If these ideas were taken up at the school level, they would have widespread implications for the organization of curriculum.

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TRENDS IN THE PRESERVICE EDUCATION OF MATHEMATICS TEACHERS

Introduction

Galbraith (1977) quotes American, British and Australian examples which suggest that conventional tertiary level courses have not provided students with the opportunity to perceive the logic of mathematics. He then describes some original research conducted within Australia which taps the extent of basic concept acquisition by prospective mathematics teachers. The average score on the test was less than forty per cent for the students who were drawn from universities and colleges of advanced education (CAEs) throughout Australia. He reports that:

> The most obvious feature is the weak performance on a test in which the emphasis was on basic mathematical knowledge and thinking rather than on manipulation of symbols or the performing of complex algorithms.
> (Galbraith, 1977:188)

Galbraith further analysed the results with respect to (a) institution type (university versus CAE); (b) extent of studies in pure mathematics (3 years versus less than 3 years); (c) recency of studies in mathematics, and (d) liking for mathematics. No significant differences were discovered between groups in any of these analyses, except liking mathematics. (Those who liked maths more scored higher.)

> There are obvious implications for teachers of mathematics at all levels. The results of (analysis) (b) suggest that mathematical appreciation and awareness is not necessarily increased by providing more of the same course. This supports the claim of Polya (1965) that an urgent need exists for different kinds of courses with different aims.

Further,

> The significant result obtained in (analysis) (d) is as interesting as it is slightly surprising... It seems surprising that less than one third of all students choosing a career in mathematics admit a strong liking for mathematics. (Galbraith, 1977:188)

There have been reports of dissatisfaction with traditional courses, not only for intending teachers but also in the preparation of mathematicians to work in industry (McLone, 1976).

With respect to mathematics education, Smith (1976b) listed the following guidelines for teacher education institutions:

1. We should identify, consistently define, and teach to the point of mastery those concepts which enable a teacher to identify and understand the difficulties that students have in learning. This task will entail the identification of all of the learning difficulties that research and wisdom of the profession now make possible, the classification of these difficulties into kinds, so as to enable the teacher to approach teaching-learning situations with a systematized body of pedagogical concepts.

2. These concepts should be taught not only verbally but by means of videotapes and films that exemplify the criterial attributes of the concepts. Packages of instructional materials should be prepared for use by the student in observing and analyzing the videotapes or films until they have mastered the defining attributes. Mastery should be determined by the student's ability to identify these attributes not only in additional films but also in normal classroom situations.

3. The skills and techniques of diagnosis and remediation should be identified and consistently defined. It will be necessary to comb the research literature as well as residues of practical experience in order to identify these elements of training. While these techniques and skills should be those for which there is reason to believe that they are effective in helping students overcome barriers to their learning, a few should be generic in the sense that they pertain to general modes of instruction.

4. Instructional materials must be contrived that will provide training in these techniques and skills under controlled conditions. These conditions can be instituted by means of videotapes and transcribed classroom discourse. By these means the individual can learn to observe his own teaching objectively, to study it, to gain the advantages of feedback, and to learn what he needs to know in order to take advantage of the feedback in improving his teaching performance.

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5. Training in the concepts, techniques, and skills should begin early in the teacher's undergraduate preparation - surely not later than the beginning of the third year. This training should be conducted in laboratories that provide adequate materials and technical means. At the same time the student should be expected to participate intermittently in the work of the school as an observer and teacher aide.

6. In order to accomplish the foregoing things it will be necessary to eliminate, at the undergraduate level, many general courses such as "introduction to education" so that the time of the student can be concentrated on the task of learning to teach. That after all is our primary responsibility. This will mean that a great proportion of the faculty of teacher institutions must become teacher trainers and cease being purveyors of information about schools and society, pedagogical ideologies and formulas that from time to time sweep through the schools. All these matters that may be relevant to the work of the teacher are better acquired in the post-baccalaureate years.

7. All that I have been trying to say can be summed up in a general way. Many of us have been critical of teachers for their failure to use the knowledge resulting from research. We have even insisted, in some cases, that they themselves become research-minded as teachers. I am suggesting that we follow our own prescription, that we use the knowledge from research about how and what teachers should be taught in order to improve the teacher training programs that we now have.

Smith's (1976b) recipe is a mixture of conservative and radical approaches. Notice, in point 6 that he dismisses general approaches based on educational theory. The emphasis is on the learning of classroom skills. Note too that, although experience in schools is considered important, he would not do away with other inputs to prospective teachers, including results of research in mathematics education.

So far in this review there has been an emphasis on American literature. The problems associated with the reanalysis of teacher education courses in mathematics have also been considered by writers in the United Kingdom. There, it is most likely that an aspiring secondary school maths teacher will complete a three or four year university course in mathematics and

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then enter a one year education program before commencing work in schools. Watson (1971) provides us with an overview of the aims of mathematics education and a discussion of the effectiveness of teacher preparation programs in this context.

He differentiates between 'second level' and 'first level' questions about the mathematics curriculum. 'Second level' questions would include 'should set theory be taught?', 'what are appropriate texts for final year programs?' 'First level' questions are of a more basic kind. They would include; 'what are we trying to accomplish?', 'what are the criteria for including set theory?'

The implications of this discussion for mathematics educators are that prospective teachers should be encouraged to analyse the nature of the subject and to see it in a curriculum context. Watson (1971) doubts whether prospective teachers can cope with the problems associated with these questions within a one year course of teacher training following a traditional university degree course in mathematics. He believes that the transition from student to effective teacher is more likely through an integrated mathematics education program which has scope for students to study courses such as: concept formation, the nature of scientific and mathematical knowledge, education and industry, and curriculum development. Running through his argument is a theme which links methods of approach in teacher education to methods of approach in schools;

> "If the teacher has had no experience of creative work of some sort, how will he be able to inspire, to lead, to help, or even to recognize the creative activity of his students? A teacher who acquired whatever he knows in mathematics purely receptively can hardly promote the active learning of his students."

Also:

> "the sort of re-examination of mathematics which one seeks to encourage involves the student in reviewing his attitude to a subject he has studied for many years; an open-minded examination of this type takes time, and to be effective requires that student shall make such attitude changes for themselves - they must as it were discover the significance of discovery method, for a 'rote-learning' acceptance of current educational doctrine will not long survive classroom experience. Whatever value this has depends greatly on the active participation of the student and the course is a demanding one."

A New Program in Mathematics Education

Howson (1975) and his colleagues at Southampton University have created programs within the Mathematics Department which they believe are more appropriate for students who do not wish to become academic mathematicians[3]. Concern about traditional mathematics courses in universities and their effects on prospective teachers were prime factors in initiating change. Howson lists the following problems. One was that teachers were unfamiliar with much of the mathematics that was being introduced into the school syllabus - for example, they lacked the mathematical background which would allow them fully to appreciate the significance of school work on transformation geometry. This was an obvious cause for alarm, but was, in fact, a symptom rather than the illness itself. The major concern for worry was that teachers had in many cases "never learned to learn" - their university and college education had turned them into absorbers of pre-digested information; they had not been encouraged or trained to accept what was offered to them, but not to question the criteria underlying the selection and methods of presentation of the material; they had not learned to view mathematics as an 'on-going' activity. Now they were being called upon to exercise judgement, to learn new mathematics, and even to write workcards, new units or text books on mathematics, yet their official 'education' had in no way prepared them for these tasks.

Resulting from this evidence, Southampton have introduced novel subjects into their program. These include:

History of Mathematics
Mathematics in Education
Project
Mathematics Curriculum Studies
Mathematical Modelling

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[3] As Sir Hermann Bondi recently pointed out, Britain has need of less than a hundred academics mathematicians a year. In fact, Cambridge by itself could cater for the country's needs. It would be of interest to carry out a similar analysis in the Australian context.

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Details of these subjects are outlined in an appendix to the article.

It is important to take note of the reactions of students, the lecturers involved and other interested parties when such an innovative approach is adopted. Howson and Griffiths (1980) have found that many students are stimulated by the different format of these programs and report extra commitment on the part of these students. Not all, however, enjoy the relative subjectiveness and openendedness of much of the work. This seems to be associated with the factual 'theorem-proof, problem-solution', examination centred approach of the traditional university. Many hesitate to make value judgements and mathematically based decisions.

Students also tended to shy away from the new subjects in the first instance. However, it was soon realised by the student body that these courses had an underlying intellectual basis and that a rigorous approach to topics was adopted. Howson (1975) remarks that:

> It is, however, with some of the 'less able' mathematicians that the courses I have described have been most successful. All these students entered university with a fair record of success of mathematics. During their time at university their confidence in their ability as mathematicians is gradually eroded. Sometimes this is because they were slow to adjust to university life and as a result lack that secure knowledge of first-year mathematics on which they might build. Yet in a different context from the traditional course they are able to show some of their talents. In dealing with lower-level mathematics and in taking their own time to assimilate their mathematics, they can begin to restore confidence in their own mathematical ability - confidence which any entrant to the teaching profession should possess.

An innovative approach always involves organizational and structural changes which affect members of staff. For some, this means a radical reappraisal of teaching methods and their relationships with students. Howson reports that difficulties were encountered in implementing new programs at Southampton. These included: keeping discussion alive and progressing purposefully, making the most appropriate use of lecturers' time outside formal classes, and comparing the reliability of assignment marking by different lecturers.

According to Griffiths (1980), there has not yet been any evidence collected which would throw light on the effectiveness of these programs

for beginning teachers. This is unfortunate. We need this type of information to aid further decision-making about innovations to prevent them ossifying.

Concluding Comment

We find in the literature a general mood of discontent about mathematics education in schools and in tertiary education institutions. There is a general reaction against courses which emphasise techniques and a call for more imaginative programs to fit students to use mathematics in industry and in teaching. Approaches which fit students to solve problems and to be able to communicate with others regarding their solution have been advocated. For prospective teachers, it is apparent that the nature of mathematical thought and the translation of basic mathematical concepts into workable curriculum programs are necessary. This may involve the use of course structures and approaches in tertiary institutions which have not yet been widely adopted.

IMPLICATIONS FOR LOCAL TEACHER EDUCATION PROGRAMS IN SCIENCE AND MATHEMATICS

The discussions contained in preceding sections were designed to provide the reader with an overview of developments in science and mathematics education in contexts similar to those faced by the Melbourne State College and other tertiary institutions intent or reappraising the nature of their offerings. Evidently, there has been discontent with some courses in colleges and universities judging by the efforts to promote change. Modifications have taken place in many facets and have affected the content, structure and methods employed. In order to analyse the implications of these changes for us, several questions are formulated below within the general framework set out by Craven (1977). He suggested that appropriate perservice courses should have components which could be listed under six headings: (1) Education for a Lifetime of Change, (2) Personalised Competency Based Programs, (3) Competence in the Subject to be Taught, (4) Interdisciplinary Studies, (5) Specialization in Teaching and Learning, and (6) Cooperation between Schools and Colleges in Preservice Education. These are convenient for considering the implications of recent trends in science and mathematics education as they apply to the local context.

(1) Education for a Lifetime of Change.

This appears to be the most nebulous of the six areas, in that it concerns affective change in students and the ways in which college and university staff affect the prospective teachers' attitudes towards lifelong learning.

What seems to be certain is that new teachers are entering school systems which are in a state of flux; there are questions about the purposes of schooling, relations between education and work, and the effects of schools on the whole education of the child. At the curriculum level, it is evident that most beginning maths and science teachers will move into other areas of responsibility within a few years of commencing work in schools. There is evidence that, even in their first years in schools, a sizeable proportion teach in subject areas for which they have no formal academic training at the tertiary level. These factors all point to the need for student teachers

and those who teach them to be aware of the need for a healthy attitude towards flexibility and change.

In the light of what has just been said, the following questions may need to be considered:

(a) To what extent should institutions such as Melbourne State College be responsible for inservice programs in the areas of mathematics and science?

(b) To what extent should links with influential bodies representing science and mathematics teachers be forged?

(c) To what extent should staff teaching at the College attempt to develop a 'professional' attitude amongst preservice science and maths students? For example, is there a case for sponsoring excursions to Conasta as a legitimate activity within the program of the College?

(d) Should College staff be responsible for encouraging students to follow their academic interests such that they influence their leisure activities; for example, should we encourage our graduates to listen to 'The Science Show' and other like programs on serious radio and television?

In summary, what are the limits of the College's responsibilities towards the socialization of young teachers, do we have the right to present a 'world view' of what we would like our teachers to do in areas which do not directly impinge on their employment as science and mathematics teachers?

(2) Personalised Competency Based Programs.

There are at least two parts to this question, the first concerns competency, the second concerns the extent to which programs should be tailored to individual needs of students. A relatively long discussion of competency based programs and alternatives to this approach has been presented earlier in this report. A decision to adopt a competency based approach in the academic or professional or both major sections of the

course would have important implications for the ways in which material is presented. Competency implies a criterion referenced approach, not a normative one often employed at the present. Although some mastery learning has been used here, it is not widespread among courses devoted to the preparation of science and mathematics teachers up to the present time.

The inclusion of the personalised component implies a divergence in the courses offered to take account of the aptitudes, interests and future intention of students. Key questions seem to be:

(a) Are there 'core' courses which are judged to be essential to all or the majority of students?

(b) To what extent should options be prepared and, given restrictions on resources, how should they be presented? (See Anderson's scheme, presented earlier, as one possible model.)

(c) Are there mechanisms which would ensure the best possible match between student needs and course structures? For example, should students be allocated to pastoral leaders at the beginning of their tertiary program?

(d) Would microteaching and self analysis techniques be the most suitable activities through which a personalised competency based program could be introduced?

(3) Competence in the Subject(s) to be Taught.

From what has been written here and from other sources, it is clear that science/mathematics teachers in Victoria are 'stretched' across curriculum areas to a greater extent than their contemporaries in other Australian states. Certainly, more is expected of them in this regard than is the case in the USA or the UK. For example, in the UK, it is most unlikely that a teacher would work in mathematics and science curriculum areas in the secondary school. The most likely pattern for a recent graduate with a science degree who teaches in the Victorian system is that she will teach mathematics,

Science and a senior school science (Owen, 1980). Alternatively, the new teacher could be expected to work in junior and senior mathematics and Science. Hence,

(a) What should be the distribution of time available which would give students the optimum opportunities for becoming familiar with the knowledge and skills needed to teach in these areas?

(b) To what extent is there on overlap between subjects designed to prepare students in each area? For example, are there key scientific or mathematical concepts, processes, etc., which could be studied by all students?

(c) What is the place, if any, of courses devoted to the study of the nature and philosophy of science and mathematics?

(d) Should we attempt to prepare teachers to cope with 'new' subjects in the senior school, e.g. Earth Science, Physical Science, Computer Studies?

(4) Interdisciplinary Studies.

Within the framework of science and mathematics education, some of the ideas which would be considered under this heading have already been introduced. It may, however, be worth casting the net wider in the spirit of a devil's advocate and ask:

(a) Whether or not there should be a 'liberal studies' stream within the structure of the four year course (see the Iowa program discussed earlier)?

Also,

(b) How should we structure courses which are designed to give Science and junior mathematics teachers the background needed for them to teach in these areas with confidence? These queries refer to both content and methods used.

(5) Specialization in Teaching and Learning.

Compared with all other secondary school subject areas , there has been far more attention paid to curriculum matters in the

areas of mathematics and science. There have been educational philosophers, psychologists and sociologists who have devoted their time to the study of one of these areas, names such as Krutetskii, Gagné, Kilpatrick and Novak come to mind as examples. The point being made is that maths and science educators such as these have much to contribute to the preparation of prospective mathematics and science teachers. Of course there are other educators outside the areas just mentioned who have made important contributions to the areas of teaching and learning. However, a noticeable trend in the more innovative teacher education courses has been to adopt an applied studies in teaching approach using the accumulated knowledge we have of factor affecting schools. In the case of science/maths teacher education programs, the focus has been on developments and examples drawn from these areas of curriculum. In examining these trends, it might be asked whether we should consider courses in:

(a) Mastery Learning,
(b) Learning by Discovery Methods,
(c) The Nature of Teaching - for example, on discipline, student-teacher interaction, the nature of the adolescent, etc.,
(d) Evaluation,
(e) Measurement and Assessment,
(f) The Sociology of the Science/Maths Curriculum,
(g) Science/Maths for Ethnic Children,
(h) The History or Philosophy of Educational Thought.

This topic approach would be in lieu of more traditional offerings in the social sciences and their implementation would probably involve cooperation between staff from more than one teaching department.

(6) Cooperation between Schools and the College.

There have been repeated references to the importance of the links between teacher preparation institutes and the schools. With respect to local programs:

(a) At what point in the program should College students first enter a school, and on what basis?

(b) What should be the relationship between staff working in the schools and those in the tertiary institutions? To what extent should one group dominate this aspect of the course program? How should these two groups interact? Who should select the supervising teachers?

(c) What voice should those representing employing authorities and schools have on the course committee? and

(d) To what extent should the course as a whole be based in the schools?

It is certain that other questions will arise in discussion. Those presented here are intended to provide some food for thought for those who are interested enough to involve themselves in the arduous tasks of planning, implementing and evaluating a new and hopefully an exciting and appropriate course in teacher education at the College.

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APPENDIX ONE: A CLASSIFICATION OF THE NEEDS OF STUDENTS IN MATHEMATICS (After Bell, 1974)

1. The main uses of numbers (without calculation)	1.1 Counting 1.2 Measuring 1.3 Coordinate systems 1.4 Ordering 1.5 Indexing 1.6 Identification numbers, codes 1.7 Ratios
2. Efficient and informed use of computation algorithms	2.1 Intelligent use of mechanical aids to calculation
3. Relations such as equal, equivalent, less or greater, congruent, similar, parallel, perpendicular, subset, etc.	3.1 Existence of many equivalence classes 3.2 Flexible selection and use of appropriate elements from equivalence classes (eg. for fractions, equations, etc.)
4. Fundamental measure concepts	4.1 "Measure functions" as a unifying concept 4.2 Practical problems: role of "unit; instrumentation; closeness of approximation 4.3 Pervasive role of measures in applications 4.4 Derived measures via formulas and other mathematical models
5. Confident, ready, and informed use of estimates and approsimations	5.1 "Number sense" 5.2 Rapid and accurate calculation with one and two digit numbers 5.3 Appropriate calculation via positive and negative powers of ten 5.4 Order of magnitude 5.5 Guess and verify procedures; recursive processes 5.6 "Measure sense" 5.7 Use of appropriate ratios 5.8 Rules of Thumb; rough conversions (eg. "a pint is a pound"); standard modules 5.9 Awareness of reasonable cost or amount in a variety of situations
6. Links between "the world of mathematics" and "the world of reality"	6.1 Via building and using "mathematical models" 6.2 Via concrete "embodiments" of mathematical ideas
7. Uses of variables	7.1 In formulas 7.2 In equations 7.3 In functions 7.4 For stating axioms and properties 7.5 As parameters

8. Correspondences, mappings functions, transformations	8.1 Inputs, outputs, appropriateness of these for a given situation 8.2 Composition ("If this happens, and then that, what is combined result?") 8.3 Use of representational and coordinate graphs
9. Basic logic	9.1 "Starting points": agreements (axioms) and primitive (undefined) words 9.2 Consequences of altering axioms (rules) 9.3 Arbitrariness of definitions; need for precise definition 9.4 Quantifiers (all, some, there exists, etc.) 9.5 Putting together a logical argument
10. "Chance", fundamental probability ideas, descriptive statistics	10.1 Prediction of mass behavior vs. unpredictability of single events 10.2 Representative sampling from populations 10.3 Description via arithmetic average, median, standard deviation
11. Geometric relations in plane and space	11.1 Visual sensitivity 11.2 Standard geometry properties and their application 11.3 Projections from three to two dimensions
12. Interpretation of informational graphs	12.1 Appropriate scales, labels, etc. 12.2 Alertness to misleading messages
13. Computer uses	13.1 Capabilities and limitations 13.2 "Flow chart" organization of problems for communication with computer